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Characterizing Disproportionate Permeability Reduction Using Synchrotron X-Ray Computed Microtomography

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Beamline: X2B

Many polymers and gels can reduce the permeability to water more than that to oil or gas. This property is critical when reducing saltwater production from oil and gas wells. However, the magnitude of the effect has been unpredictable from one application to the next. Presumably, the effect would be more predictable and controllable if we understood why the phenomenon occurs. Although many mechanisms have been considered, the underlying cause of the disproportionate permeability reduction remains elusive.

X-ray computed microtomography was used to investigate why gels reduce permeability to water more than that to oil in strongly water-wet Berea sandstone and in an oil-wet porous polyethylene core. Although the two porous media had very different porosities (22% versus 40%), the distributions of pore sizes and aspect ratios were similar. A Cr(III)-acetate-HPAM gel caused comparable oil and water permeability reductions in both porous media. In both cores, the gel reduced permeability to water by a factor 80 to 90 times more than that to oil. However, the distributions of water and oil saturations (versus pore size) were substantially different before, during, and after gel placement.

The disproportionate permeability reduction appeared to occur by different mechanisms in the two porous media. In Berea sandstone (see Figs. 1-6), gel caused disproportionate permeability reduction by trapping substantial volumes of oil that remained immobile during water flooding. With this high trapped oil saturation, water was forced to flow through narrow films, through the smallest pores, and through the gel itself. In contrast, during oil flooding, oil pathways remained relatively free from constriction by the gel.

In the polyethylene core, oil trapping did not contribute significantly to the disproportionate permeability reduction. Instead, oil films and a relatively small number of pore pathways provided conduits for the oil. For reasons yet to be understood, the small pore pathways appeared largely unavailable for water flow.

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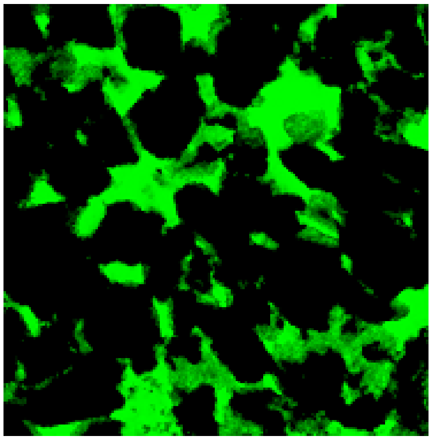

Fig. 1—Rock saturated with water only.

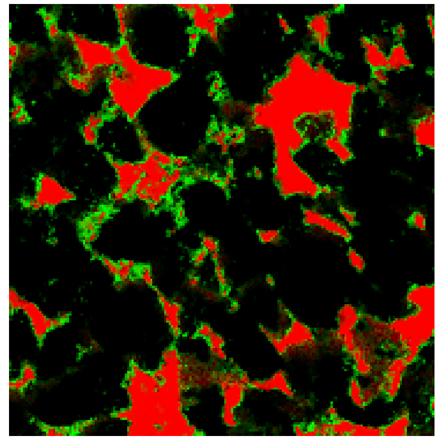

Fig. 2—Oil flow before gel.

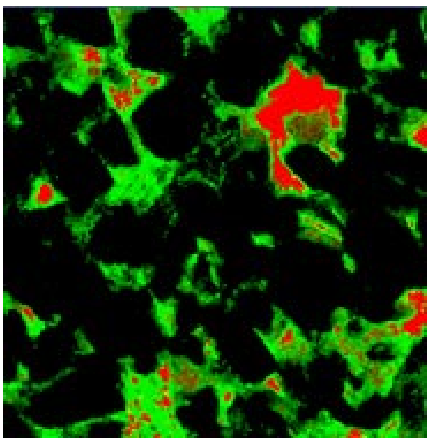

Fig. 3—Water flow before gel.

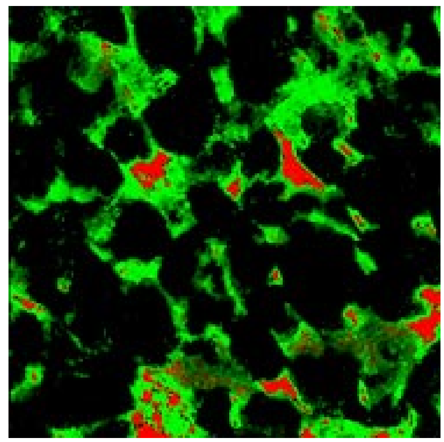

Fig. 4—After gel placement.

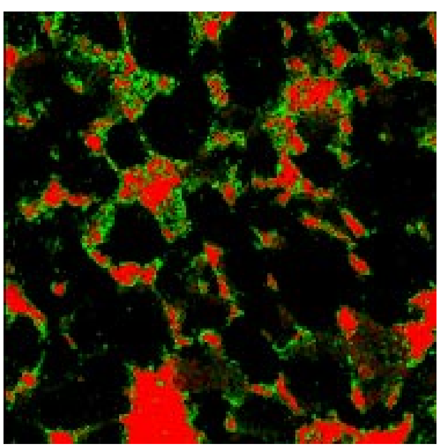

Fig. 5—Oil flow after gel.

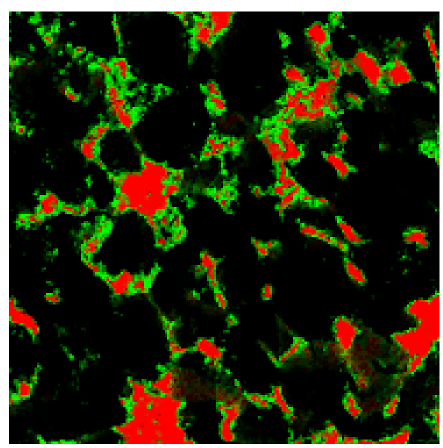

Fig. 6—Water flow after gel.

Berea sandstone cross-sectional image slices (1.15 mm x 1.15 mm each).
Green is water. Red is oil. Black is rock.